Space Weather Technical Forecast

Issued on Sunday, 10 December 2023 at 01:08 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Chance of M-flares throughout.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate, with peak flare M1.5 from AR3511 at 09/0955 UTC. This is the most active of nine sunspot regions on the disc, eight of which are numbered. AR3511 is a longitudinally wide region approaching the southwest disc, and while this has exhibited a decaying trend, maintains sufficient complexity for the potential for similar flares. AR3513 was the most developmental region, with ongoing growth in its intermediate area, but remained stable as it moved into the north-centre disc. A large far-sided filament eruption was observed off the north of the solar disc, however no Earth-directed CMEs were observed.

Solar Wind / Geomagnetic Activity: Slow wind conditions were observed throughout. Solar wind speeds observed by ACE and DSCOVR were near or at background, around 400km/s, with at or below average density. Total Interplanetary Magnetic Field (IMF) Bt, was weak, below 5nT, while the north-south component varied between +5nT and -4nT. Phi angle was predominately negative (towards the Sun). Geomagnetic activity was Quiet (Kp 0-1)

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux remained at Background levels. GOES16 high energy (greater than 2MeV) electron flux was mainly Moderate, but briefly High, peaking 1130pfu at 09/1450UTC. The associated 24-hour fluence has remained below the Active threshold (1e8 integrated pfu). The observation at 10/0000UTC was 5.03e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low to Moderate activity is forecast with a likelihood of further isolated M-flares, predominately from AR3511 in the southwest or AR3513 in the north-centre disc.

Solar Wind / Geomagnetic Activity: A weak CME may give a glancing interaction late on day 1 (10 Dec), however this is very low confidence. Otherwise, current background solar winds have the potential to become slightly elevated due to the onset of any fast wind arrival from CH77/+, or perhaps CH80/+. This is most likely day 1 into day 2 (10-11 Dec), as indicated in enlil, however confidence is low due to the coronal holes being difficult to see, largely obscured in SDO imagery. Any enhancement is likely to ease on days 3-4 (12-13 Dec). Quiet geomagnetic activity is forecast to become Unsettled with a spell of Active from any CME enhancement, along with a slight chance of G1 Minor Storm intervals, mainly later day 1 or day 2 (10-11 Dec). Activity then easing to be mainly Quiet with isolated Unsettled intervals late day 2 onward.

Energetic Particles / Solar Radiation: GOES16 high energy proton is expected to persist at background levels, with only a slight chance of rising towards the S1 Minor Radiation Storm level given any significant flares from AR3511, or perhaps AR3513 given further growth as it moves into the western disc. High energy electron flux is expected to be mainly Moderate, briefly High, at first but dropping out with any solar wind enhancement later day 1 or day 2 (10-11 Dec), before recovering to mainly Moderate levels later in the period. The associated 24 hour fluence is expected to remain below the Active (1e8 integrated pfu) threshold.

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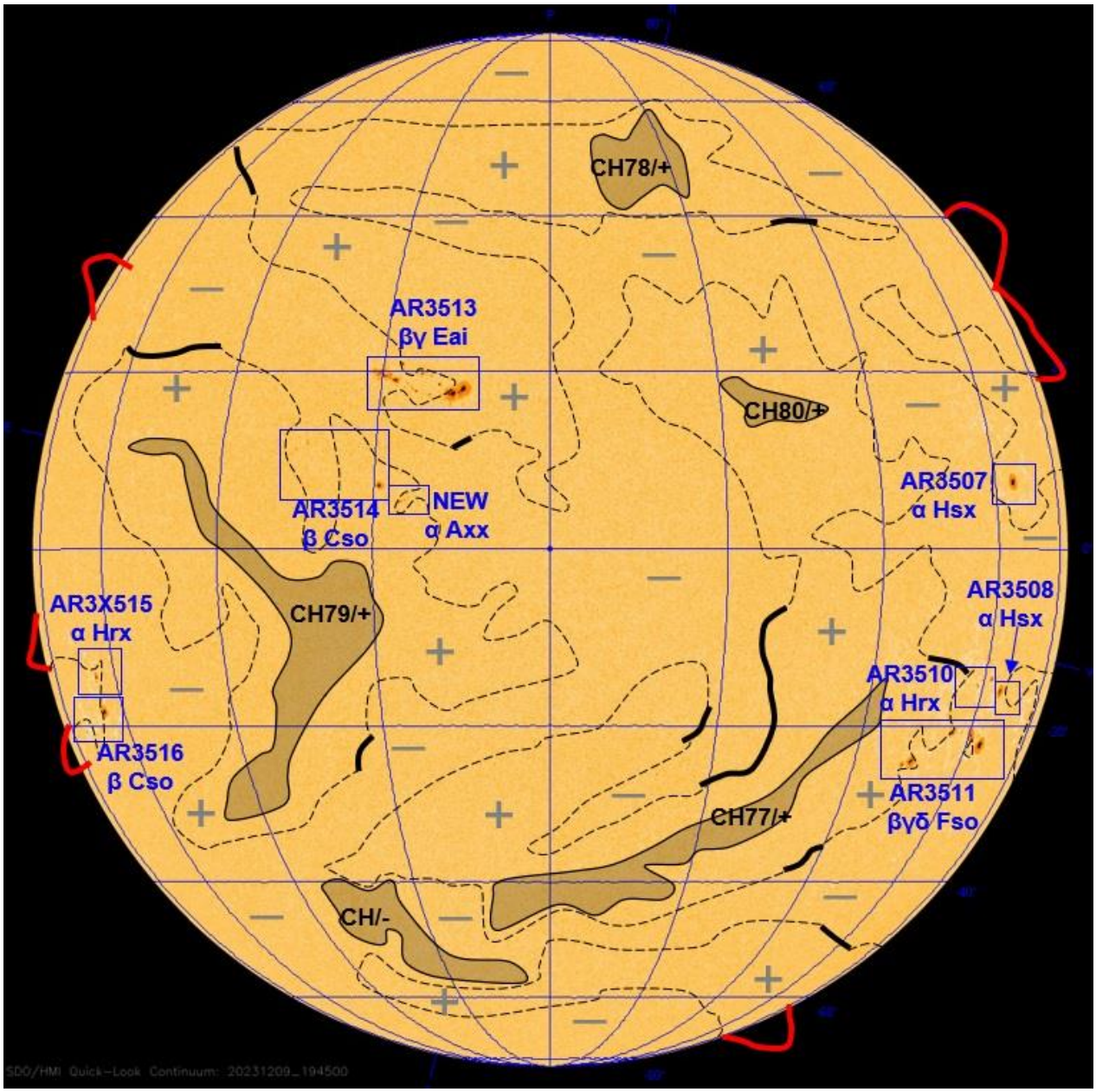
Figure 1. Solar Analysis Valid 09/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There are no Earth-directed CMEs that are expected to have a significant influence on geomagnetic conditions, however there is a low confidence glancing impact possible late on day 1(10 Dec) from a CME which left the northeast disc due to a filament eruption around 07/0200 UTC.

This CME may arrive alongside a weak enhancement from the southern coronal hole CH77/+, currently forecast for later day 1 (10 Dec). This is a narrow feature that is becoming hard to see amongst other coronal loops in SDO aia-imagery, but was clear in the southern centre disc on 07 Dec. There is also the very small and largely obscured CH80/+ in the northern disc. This was observed opening in SDO aia imagery on 08 Dec, and quickly underwent morphological changes. While now very hard to see, it is aligned with CH77/+, perhaps increasing the potential for Earth to see some aspect of fast wind enhancement occurring. This enhancement is indicated in enlil solar winds, however due to the obscured nature of the coronal holes confidence remains low.

Overall current background winds are likely to become slightly elevated (450-500 km/s) later on day 1 and into day 2 (10-11 Dec), with Quiet geomagnetic activity increasing to be Unsettled with Active intervals, and a slight chance of G1 Minor Storms. Activity soon easing to be mainly Quiet, with only isolated Unsettled intervals from late day 2 onward (11 Dec), as solar winds also ease back towards background day 3 (12 Dec) onward.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	10	10	1	1
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
07/1302	Nil	Filament	NE	406 km/s	Late 10 Dec	Very low confidence. Glancing impact at most.

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Figure 2a: Enlil showing fast wind onset, and weak CME glance.

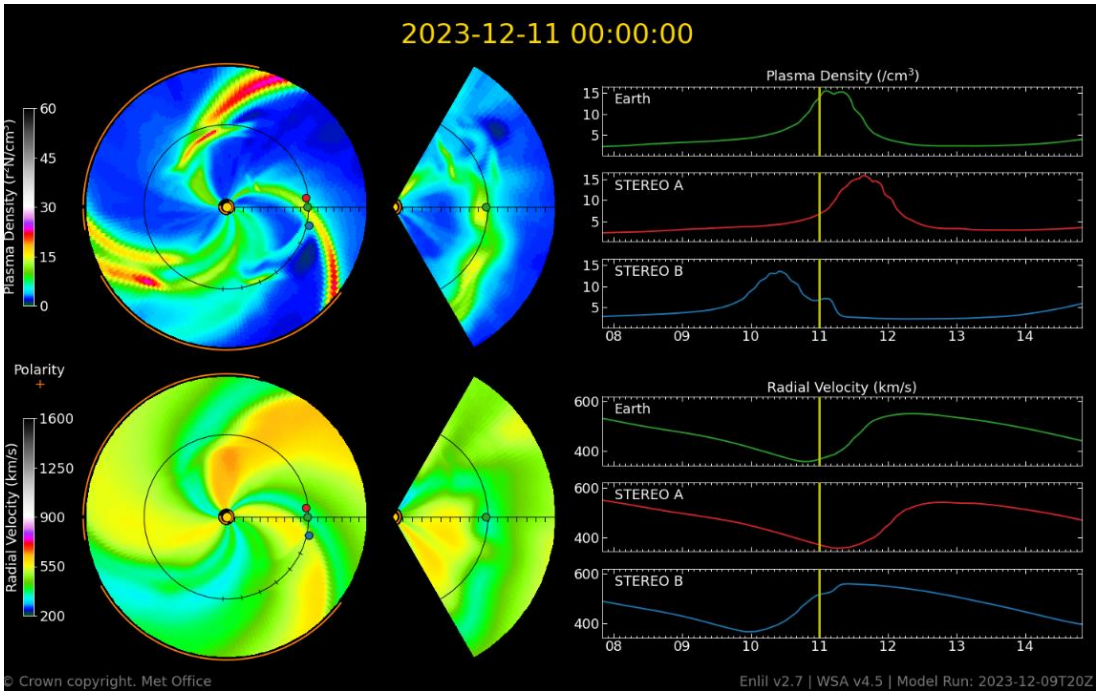
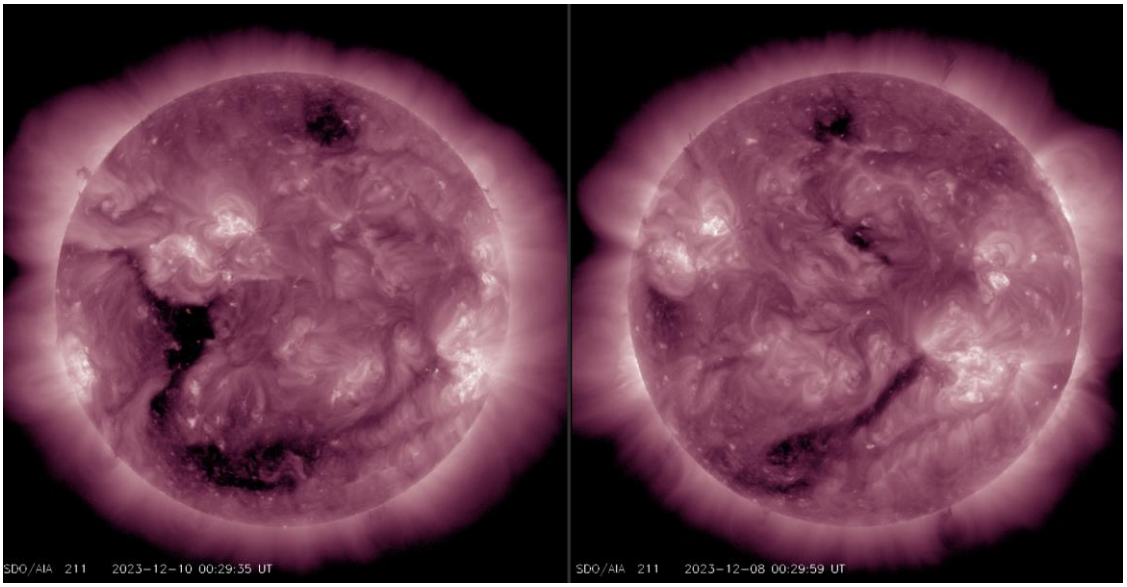


Figure 2b SDO aia 211 current (left) and on 08 Dec (right). CH77/CH80 more visible when centre disc, but now difficult to make out due to narrow/small nature of coronal holes and surrounding coronal loops.



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Radio Blackouts - X-Ray Flares:

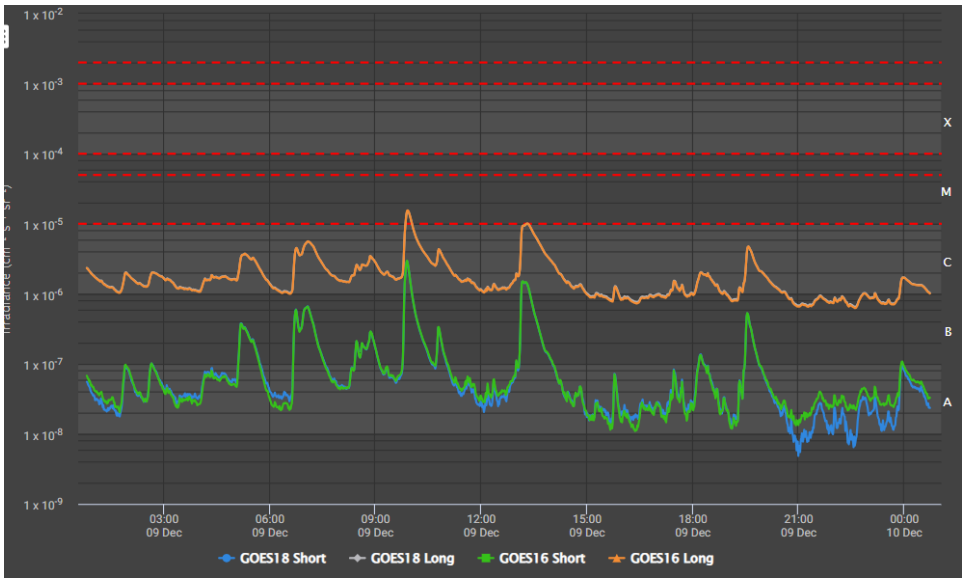
Low to Moderate activity is expected to continue with a likelihood of further isolated M-flares.

Of the nine sunspot regions on the disc, the main flaring risk is from AR3511, now approaching the southwest limb and AR3513 nearing the north-centre disc. AR3511 is longitudinally wide but also relatively small in areal extent, and was the source of recent M-flaring during the last 36 hours, due to the development of at least one delta spot. The main delta spot appears has subsequently faded, however there remains a very small potential delta amongst its intermediate spots near the main leader, although due to the regions proximity to the limb this is becoming harder to observe. Further M-flaring is possible from this spot. AR513, while less active, is also moderately sized and has shown the most growth on the disc with the emergence of a number of intermediate spots, including a reverse polarity spot to the north of its trailer. Further growth could have a destabilising effect, also bringing a risk of M-flares.

The other regions on the disc are generally small, simpler and currently either stable or showing signs of decay.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	60	55	50	45
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 3: GOES 16-18 X-ray flux



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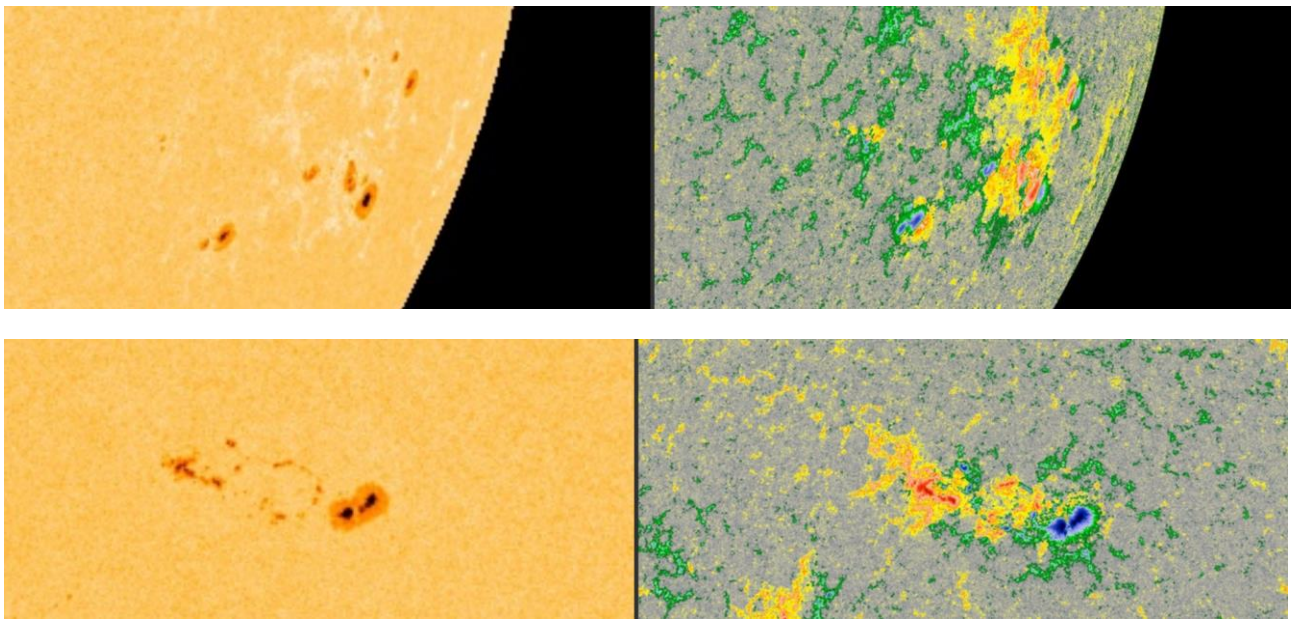
Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at Background. There is a slight chance of this increasing given the occurrence of any further significant flares on the disc, especially from AR3511 in the southwest, and also from AR3513 if any further growth occurs as it moves into the western hemisphere. However, this only brings a very slight chance of reaching the S1 Minor Radiation Storm level.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	10	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: SDO intensitygram and magnetogram of the cluster of sunspots in the southwest including AR3511 (top) and AR3513 (bottom)



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High Energy Electrons Event (≥ 2MeV):

High energy electron flux, as observed by GOES-16, has been mainly Moderate with only brief diurnal peaks at High, since the solar wind enhancement from CH76. This is expected to persist at first day 1 (10 Dec), before dropping more persistently to background with any subsequent enhancements from either CH77/+ or CH80/+, along with any CME glance that may occur later in the day or on day 2 (10-11 Dec). Some recovery in flux, to mainly Moderate levels, is then likely day 3-4 (12-13 Dec), with a slight chance of peaking High.

The associated 24 hour fluence is expected to remain below the Active threshold through the period. This is supported by REFM, with the initial declining fluence likely, but with a chance of then rising days 3-4 (12-13 Dec).

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	1	1	1	5
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 5: GOES-16 >2MeV Electron flux and Fluence with REFM

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